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REPORT NO T94-2

MAXIMUM TEAM LIFTING CAPACITY AS A FUNCTION OF TEAM SIZE

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

OCTOBER 1993

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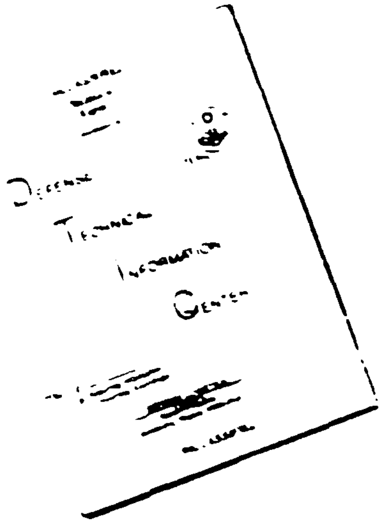

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE
Maximum Team Lifting Capacity as a Function of Team Size

5. FUNDING NUMBERS

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute of Environmental Medicine
Occupational Physiology Division
Natick, MA 01760-5007

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The relationship between the sum of individual lifts and team lifting capacity in two-, three-, and four-person teams was examined. Twenty-three men and 17 women were assigned to single and mixed-gender teams of two, three or four persons. A weight-lifting bar was used to measure individual deadlift, as square device for two- and four-person lifting and a triangular device for three-person lifting. Team lifting capacity increased with team size and with the number of males on the team. Team lifting capacity as a percent of the sum of deadlift strength (% sum) did not change with an increase in team size beyond two. The %sum for teams of men (87.3%) was less than for teams of women (91.1%, $p<.05$), and the %sums for single gender teams were both greater ($p<.01$) than for mixed-gender teams (80.2%). The limits for lifting set by Military Standard 1472D (1989) are well below the capabilities demonstrated here, and there is ample evidence in the Military Occupational Classification Structure (1990) that soldiers are required to lift heavier loads than recommended. Since soldiers are capable of and required to lift more than the recommended loads, consideration could be given to increasing these design limits.

14. SUBJECT TERMS
lifting, team lifting, teamwork, muscle strength, manual materials handling, isometric strength, male, female

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	unlimited distr.

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TECHNICAL REPORT

MAXIMUM TEAM-LIFTING CAPACITY AS A FUNCTION OF TEAM SIZE

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October 1993

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EXECUTIVE SUMMARY

Teamwork is recommended for lifting very heavy objects, but the effect of increasing team size on cumulative lifting ability is not well defined. In this study, the relationship between the sum of individual lifts and team-lifting capacity in two, three- and four-person teams was examined. Twenty-three men and 17 women were randomly assigned to single and mixed-gender teams of two, three and four persons. A standard weight-lifting bar was used to measure individual dead lift (floor to standing); a square device was used for two- and four-person lifting and a triangular device was used for three-person lifting. Team-lifting capacity increased with an increase in team size and with an increase in the number of males on the team. Team-lifting capacity as a percentage of the sum of individual lifting strength (% sum) was calculated for each team size and gender combination. There was no significant difference in % sum due to team size. The % sum for teams of men (87.3%) was significantly less than for teams of women (91.1%, $p<.05$), and the % sums for single-gender teams were both significantly greater ($p<.01$) than that for mixed-gender teams (80.2%). The limits set for individual and team lifting by Military Standard 1472D (1989) are well below the capabilities demonstrated here. There is ample evidence in the Military Occupational Classification Structure (Department of the Army, 1990) that soldiers are required to lift heavier loads than recommended. Since soldiers are capable of and required to lift more than the recommended loads, consideration could be given to increasing these design limits.

INTRODUCTION

In industry, it is recommended that individuals work in teams to accomplish heavy lifting tasks, particularly when the object is bulky. For a single lift from floor level to a height of 1.5 m, Military Standard 1472D (1989) stipulates that men should not lift more than 25.4 kg and women should not lift more than 16.8 kg. For two-person lifts, the standard recommends doubling this load, and for three-person lifts, "...not more than 75% of the one-person value may be added for each additional lifter ...". The Military Occupational Classification Structure (Department of the Army, 1990) provides many instances where these standards are exceeded. For example, a 155 mm Howitzer round weighs 45 kg and is loaded into the breech by one person. During the resupply process, more than 100 of these 45 kg rounds may be lifted from the ground into the howitzer in a ten-minute period.

Although no women are currently enlisted as a howitzer crew member, a physically demanding MOS employing a large number of women is the Medical Specialist (91A). Medical Specialists treat injured soldiers and may be required to move them from the field into an ambulance on a hand-held litter. Army doctrine requires that four people carry a litter but certain vehicles do not provide adequate space for a four-person team. The litters are then carried by two or three people. Based on Military Standard 1472D (1989), two women should not lift a patient weighing more than 38 kg (84 lbs) and four women should not lift patients weighing more than 66.5 kg (140 lbs). The 50th percentile male soldier weighs 78 kg (171 lbs), while the 50th percentile female soldier weighs 62 kg (135 lbs) (Gordon et al., 1988). According to this military standard, four female soldiers can safely lift the average female soldier, but should not lift the average male soldier.

The objectives of this study were to examine the effect of team size on team-lifting capacity, to determine the effects of various gender groupings on maximal team-lifting capacity and to correlate individual measures of strength and body size with team-lifting capacity.

REVIEW OF LITERATURE

Isometric and isokinetic team-lifting capacity has been studied for teams of two and three men (Karwowski & Mital, 1986) and two and three women (Karwowski & Pongpatanasuegsa, 1988). Karwowski and Mital (1986) reponed that the team-lifting capacity of men was less than the sum of individual lifting strengths and this deficit increased when the numbar of men lifting increased from two to three. The team-lifting capacity of two women was less than the sum of individual strengths, but showed little or no further decline with the addition of a third woman (Karwowski & Pongpatanasuegsa, 1988). Although no statistical comparison was made, the percentage difference between the sum of individual lifting strengths and team-lifting capacity appeared to be lower in women than in men for isometric strength, but not for isokinetic strength.

Lack of team coordination during the lifting movement was one reason cited to explain the decrease in cumulative strength when isokinetic teams were compared to isometric teams (Karwowski & Mital, 1986; Karwowski & Pongpatanasuegsa, 1988). If team coordination decreases during an isokinetic movement, where speed of movement is controlled, it should deteriorate further when lifting at an uncontrolled rate, such as lifting a large object. This hypothesis was not supported by an additional study conducted by Karwowski (1988). Teams of two men or two women determined the maximum weight tney could lift from floor level to 89 cm at the infrequent rate of 2 lifts/hour (Karwowski, 1988). Pairs of men lifted 87.5%, and pairs of women lifted 91.0% of the sum of their individually determined maximum acceptable lift. The average female to male team-lifting capacity ratio for pairs was 69.6%, which is higher than the female to male ratio of 60% reported in the literature for individual lifting strength (Myers et al., 1984; Sharp et al., 1980; Teves, Wright & Vogel, 1985). It is therefore unclear whether differences exist in the manner in which men and women respond to team-lifting tasks.

There are no reports of lifting strength for combined gender teams in the literature. Combined gender teams exist in the military and civilian work force, therefore it is important to know the relationship between individual strength and

team-lifting capacity for a combined gender team.

The objectives of this study were: 1) to examine the relationship between the sum of individual lifting strengths and team lifting capacity for isotonic (isoinertial) lifting in teams of two, three and four; 2) to make direct gender comparisons in team lifting ability; and 3) to determine the correlations between individual strength and body size measurements and team-lifting capacity.

METHODS

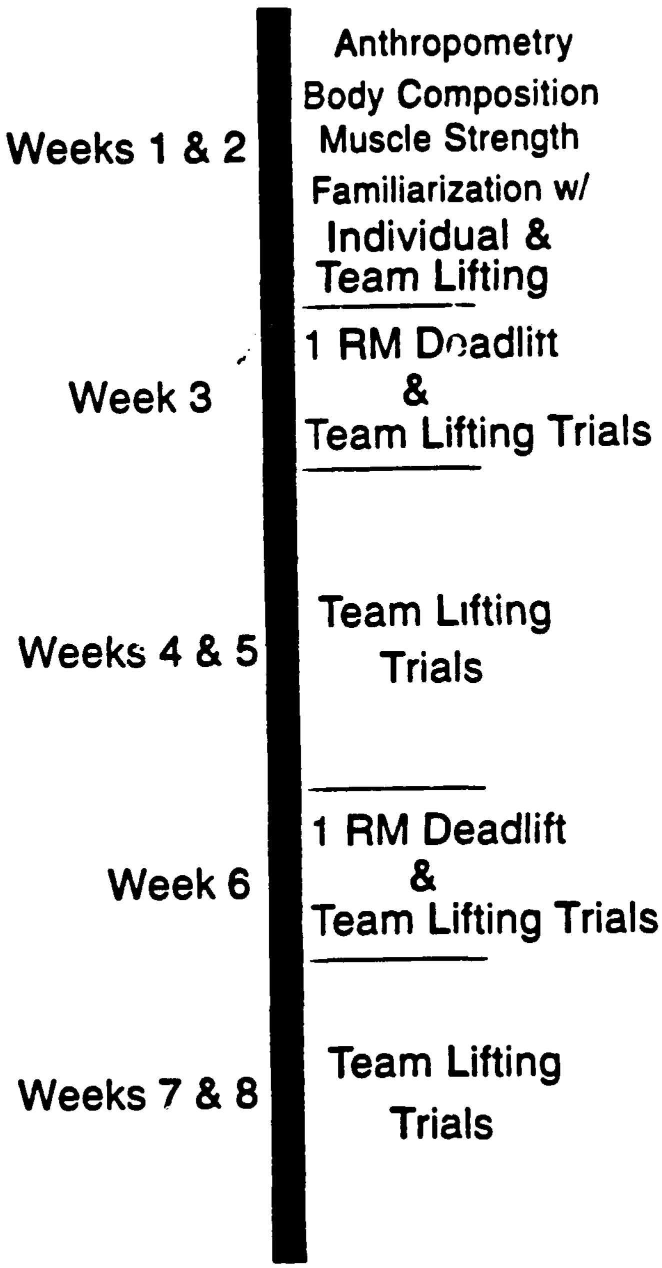
SUBJECTS

Twenty-three male and 17 female subjects participated in the study. Written informed consent was obtained from each participant following a detailed briefing. All subjects were medically screened prior to participation in any testing procedure. Subjects were assigned to teams on a random basis for two- and three-person lifting to obtain equal numbers of male, female and mixed-gender teams. Four-person teams consisted of two teams of previously selected pairs that were randomly assigned to lift together.

ORDER OF TESTING

The testing sequence is illustrated in Figure 1. During weeks one and two, anthropometric and body composition measurements were made, strength testing was conducted and subjects were familiarized with the individual and team-lifting capacity tests. During week three, subjects performed the individual one repetition maximum dead lift strength determination and began team-lifting trials. Team-lifting trials were conducted during weeks three through five. Maximal individual dead lift strength was reassessed at the beginning of week six. Additional team-lifting trials were conducted during weeks six through eight.

Figure 1. Time line of data collection.



The above sequence was conducted twice; first for three-person lifting, then for two- and four-person lifting. Lifting trials with same gender teams were conducted before mixed-gender trials for the three-person lifting study. The second experiment (two- and four-person lifting) was conducted with two weeks of single-gender lifting, three weeks of mixed-gender lifting and a final week of single-gender lifting.

TEAM-LIFTING CAPACITY

One determination of maximum lifting strength was conducted per day with 48 hours rest between testing sessions. Subjects attended a supervised 30-min stretching session on intervening days and stretched before and after each lifting trial.

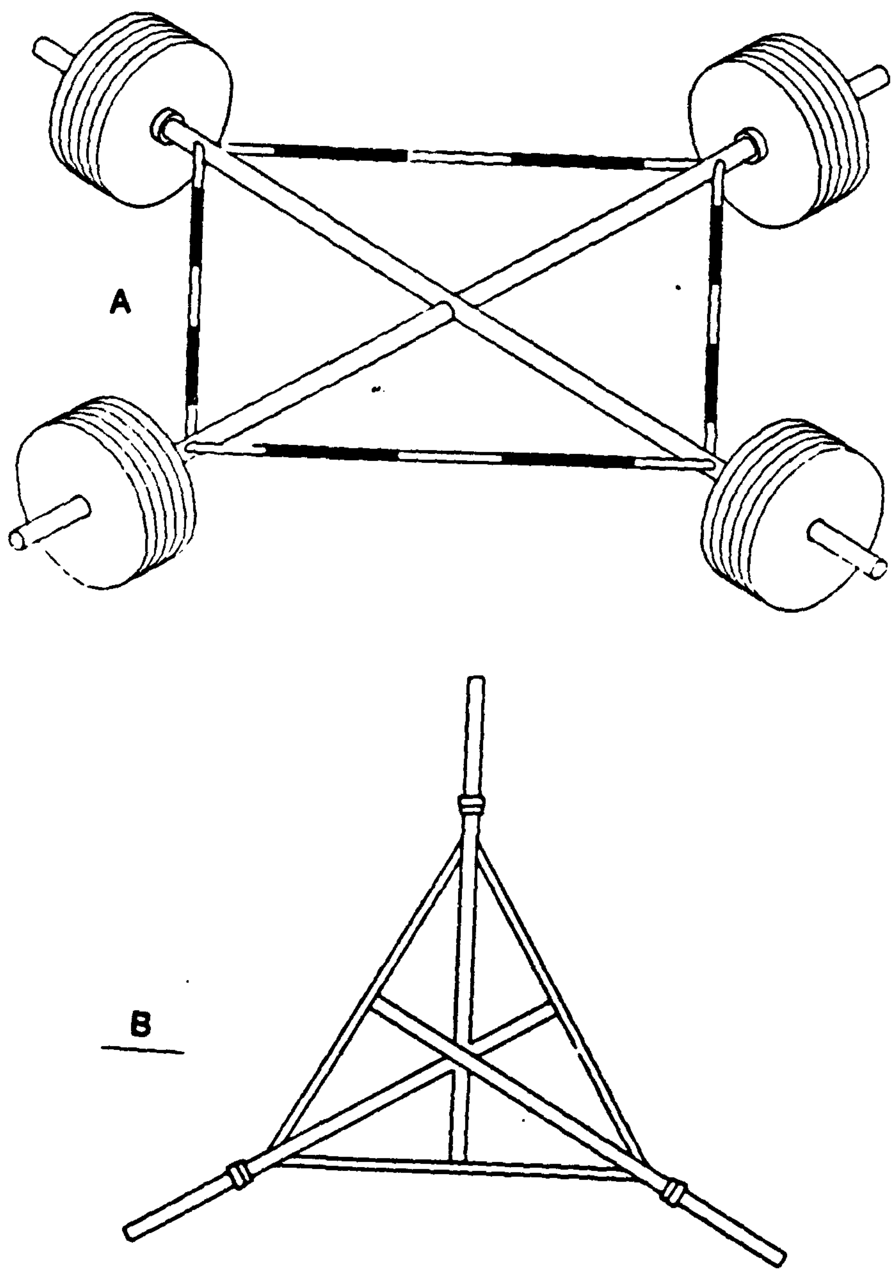
Device

Two- and four-person team-lifting capacity was measured using the weight-lifting device shown in Figure 2a, which weighed 68.6 kg. The device in Figure 2b was used for three-person lifting, and weighed 64.3 kg. The devices were designed to be similar to the standard weight-lifting bar used to measure individual dead lift strength. Both devices had reinforcing center bars and extensions to hold weight plates which extended beyond the triangular or square shape.

Testing Procedure

The lift cadence used was: "feet ready, hands ready, down and lift". On "feet ready", the subjects placed the balls of their feet shoulder width apart and directly below the bar. On "hands ready", the subjects bent over and grasped the bar with one palm facing forward and one palm facing backward. On "down", the subjects assumed a semi-squat position, with their head up, their back straight and both feet flat on the ground. On "lift", subjects attempted to lift the bar using a smooth continuous motion, from floor level to the full standing position of the shortest team member. Technicians assisted the team in lowering the load. If a team member was unable to safely complete the lift, technicians took the load and

Figure 2. a) Two- and four-person lifting device. b) Three-person lifting device.



lowered it to the ground. The team lifting procedure is illustrated in Figure 3.

Each team lifted the unloaded bar three times to warm up. Weight was then added to the device with each lift in increments of 15-40 kg until the team was unable to complete the lift, i.e., smooth motion to the knuckle height of the shortest lifter. As the team approached its maximum load, the increment was reduced. When a team was unable to complete a lift, the load was reduced in small increments (3-10 kg) until a lift was completed, or, until the last load lifted successfully (prior to first failure) was reached. Five or six lifts were generally needed to reach maximum-lifting capacity.

Weight-lifting belts and gloves were available for use but subjects were not required to use them. If proper form was not adhered to, the lift was not accepted. Adequate rest (3 min) was provided between lifts as the maximum load was approached (Fleck & Kraemer, 1987).

ADDITIONAL MEASURES MADE DURING TEAM LIFTING TRIALS

Before and after each team lifting trial, subjects completed a pain, soreness and discomfort questionnaire indicating on a scale of 0-5 the degree of pain, soreness and discomfort they were currently experiencing in the front and back of each of eleven body parts (Knapik et al., 1990). The purpose of this questionnaire was to monitor the subjects for injury, and to determine if different team sizes or gender configurations affected the perceived discomfort of the lift. Following each team lifting trial, subjects provided a rating of perceived exertion according to the Borg scale (Borg, 1982) and a team cohesiveness survey (Knapik et al., 1987). The purpose of the Borg scale was to determine how hard the subjects perceived they were exercising and to compare this to the various team size and gender combinations. The purpose of the team cohesiveness survey was to determine if certain gender groupings or team sizes were more acceptable to the subjects. The team cohesiveness survey is typically used for groups that work together for an extended time period, however no alternative test was found to examine this issue. Samples of the pain, soreness and discomfort diagram, the Borg scale and the Team Cohesiveness Survey are in Appendix.

Figure 3. Team lifting procedures: a) start of four-person lift, b) middle of three-person lift, c) finish of two person lift.

STRENGTH MEASURES

Several different measures of muscular strength were made to correlate with team-lifting capacity. One repetition maximum (1RM) dead lift strength was measured using a procedure identical to that of team lifting but with no verbal cues. Figure 4 depicts the 1RM dead lift. As with team-lifting capacity, the load increment was reduced as the subject approached his/her maximum. The load was decreased following the first failure to determine the maximum lift as accurately as possible. A minimum of three-minutes rest was provided between lifting attempts and proper technique was enforced.

Maximum machine lifting strength was measured on an incremental dynamic lift device as shown in Figure 5 (McDaniel, Skandis & Madole, 1983). Subjects lifted a weight stack on a vertical track from the floor to 152 cm height. Additional weight plates were added with each attempt until the maximal-lift capacity was reached (Teves, Wright & Vogel, 1985).

Isometric lifting strength was measured using the 38 cm upright pull as displayed in Figure 6 (Knapik, Vogel & Wright, 1981). A similar test has been used as a pre-employment screening test in industry (Chaffin et al., 1977). The test required the subject to assume a semi-squat position while gripping a round, taped aluminum handle. The 38 cm high handle was attached by cable to a load cell mounted on a slip-free wooden platform. The maximum pulling force produced was measured with a load cell and registered on a digital readout. The highest two of three trials within 10% of one another was averaged to obtain upright pulling strength.

Figure 4. Measurement of one-repetition-maximum dead lift.

Figure 5. Maximal machine lifting test.

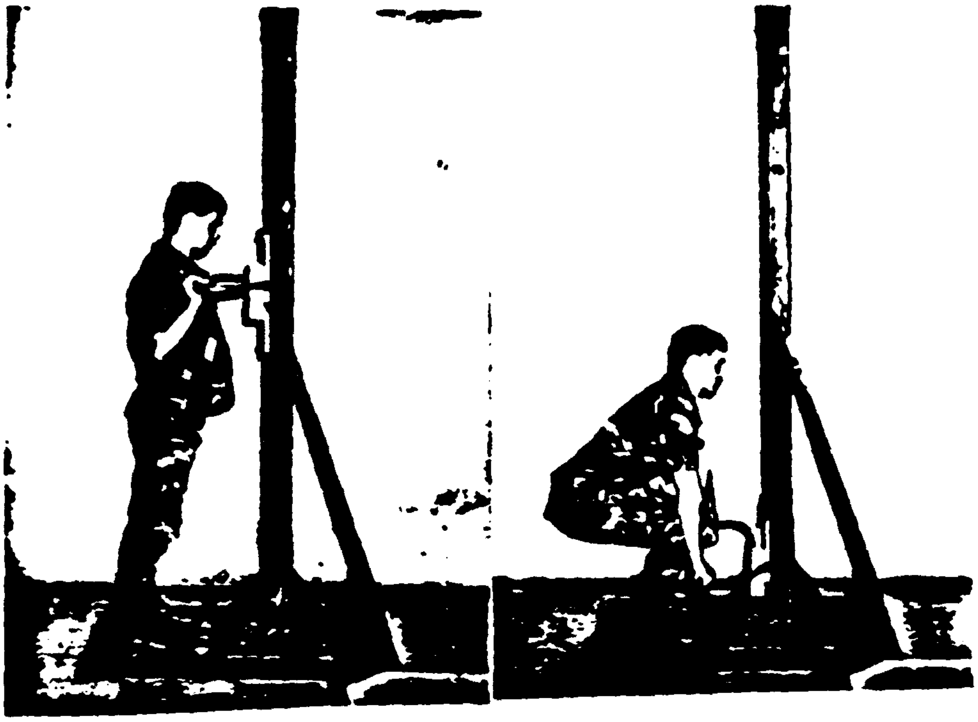


Figure 6. Maximal isometric lifting strength test.

ANTHROPOMETRY

Anthropometric measurements were made to describe the sample in relation to typical Army populations and to determine their relationship to team-lifting performance. In addition to height, weight, and age, the following anthropometric measures were made:

1. trochanter height - the vertical distance from the standing surface to the most superior point of the greater trochanter of the femur.
2. sitting height - the vertical distance between a sitting surface and the top of the head. Subject sits erect with the head in the Frankfort plane.
3. sleeve outseam - the straight-line distance between the acromion landmark on the tip of the right shoulder and the stylion landmark on the right wrist.
4. hand circumference - the circumference of the hand measured over the metacarpal-phalangeal joints.
5. fist circumference - the circumference of the clenched fist (with the thumb lying across the end of the fist) measured with the tape passing over the thumb and the knuckles.
6. grip diameter - the inside diameter of the circle formed by the first and third phalanges. Subject moves hand down a wooden cone with markings every .25 cm. The score is the greatest diameter that can be attained with the first and third phalanges still touching.

BODY COMPOSITION

The body composition of subjects was assessed using hydrostatic weighing. Residual volume was measured in duplicate using the oxygen dilution method (Fitzgerald et al 1987). If the difference between two trials was greater than 50 mls, a third trial was performed. Subjects were tested sitting in a chair and leaning forward to duplicate the position in the underwater weighing tank. Subjects performed 7 to 10 underwater weighing trials to residual volume underwater (Fitzgerald et al, 1987). All subjects wore a nose clip to duplicate the residual volume measurement procedure. The two trials which produced the highest values

within 20 grams of each other were averaged and used in the calculation of density (Siri, 1961). Density was calculated with a correction factor of 100 mls for gastrointestinal gas.

DATA ANALYSIS

The mean and standard deviation for the total group by gender were calculated for the descriptive strength and anthropometric measurements. Two-way analysis of variance was used to compare team size (two-, three-, and four-person teams) and gender combinations (all male, all female and mixed-gender teams) for the variables associated with team lifting (team lift (kg), % sum, team cohesiveness, RPE, and pain, soreness and discomfort). All three-person team lifting data were subjected to a second, separate analysis to examine the four gender groupings (all male, all female, two men with one woman, and one man with two women). Tukey HSD post-hoc tests were performed to determine significant differences between means for the analyses of all team sizes and for the separate three-person analyses. The strength and body size measurements were correlated with team-lifting capacity and a regression equation was developed to predict team-lifting capacity.

RESULTS

SUBJECT DESCRIPTORS

The mean and standard deviation of descriptive measurements for the total sample by gender are listed in Table 1. Males were significantly younger, taller, weighed more, had more fat-free mass and less body fat. The women were average weight and height, but the men were taller than average and represented the 70th percentile Army population (Gordon et al., 1988). The body composition (percent body fat and fat-free mass) of both genders was similar to that of an age matched Army population (Fitzgerald et al., 1986).

Table 1. Physical characteristics of subjects.

	Men (mean ± SD)	Women (mean ± SD)
n	23	17
age (yr)	20.3 ± 1.7	26.7 ± 6.4[1]
height (cm)	177.9 ± 6.4	163.3 ± 4.2[2]
weight (kg)	76.3 ± 12.2	61.1 ± 7.8[2]
percent body fat	16.8 ± 6.2	26.1 ± 5.5[2]
fat-free mass (kg)	62.9 ± 8.0	44.7 ± 4.7[2]

[1] Significantly different from men ($p<.05$).
[2] Significantly different from men ($p<.01$).

The means and standard deviations for the muscle strength measures are listed in Table 2. Men were significantly stronger ($p<.01$) than women on all strength measurements. The male average machine lifting strength represented the 92nd percentile for Army men (Sharp & Vogel, 1992), while the female average was identical to that from a recent sample of new female recruits (Sharp, unpublished data). The isometric lifting strength was equivalent to the 80th percentile of Army men and women (Sharp, 1993). Dead lift strength was measured at the beginning and midway through the study. A one-way analysis of variance with repeated measures was used to determine if increases in individual lifting strength had occurred. There were significant gender ($p<.01$), time ($p<.01$, pre- to mid-study), and gender by time ($p<.05$) effects. For both genders combined, dead lift strength increased 5% during the first half of the study ($p<.01$). Post-hoc analysis of the interaction effect ($p<.01$) revealed that men and women were significantly different from one another before, and midway through the study, but neither gender increased significantly from measurement one to two. The test-retest reliability coefficient for dead lift strength was 0.98.

The means and standard deviations for the anthropometric measurements are listed in Table 3. Men were significantly different from women on all measurements ($p<.01$).

Table 2. Maximal strength measurements (kg) for men and women ($\bar{X} \pm SD$).

	Men	Women	female-to-male ratio
n	23	17	
Dead lift	137.0 ± 22.1	84.7 ± 14.2[1]	.62
Machine lift	79.4 ± 13.4	39.8 ± 6.6[1]	.50
Isometric lift	144.6 ± 32.0	87.6 ± 18.2[1]	.61

[1] Significantly different from men ($p<.01$).

Table 3. Anthropometric measurements for men and women ($\bar{X} \pm SD$).

	Men	Women
n	23	17
trochanteric height (cm)	95.2 ± 5.6	86.3 ± 3.8[1]
seated height (cm)	91.4 ± 3.9	85.2 ± 2.8[1]
sleeve outseam (cm)	62.4 ± 2.8	57.8 ± 2.7[1]
hand circumference (cm)	21.3 ± 1.2	18.3 ± 1.4[1]
fist circumference (cm)	27.8 ± 1.2	23.2 ± 2.0[1]
grip diameter (cm)	2.11 ± 0.14	1.88 ± 0.17[1]

[1] Significantly different from men ($p<.01$).

TEAM-LIFTING CAPACITY

Test-retest Reliability

The test-retest reliability of team lifting was assessed using eight teams of subjects who, by chance, were selected to lift together more than once during the

conduct of the test. The test-retest correlation was $r=0.98$ ($p<.01$).

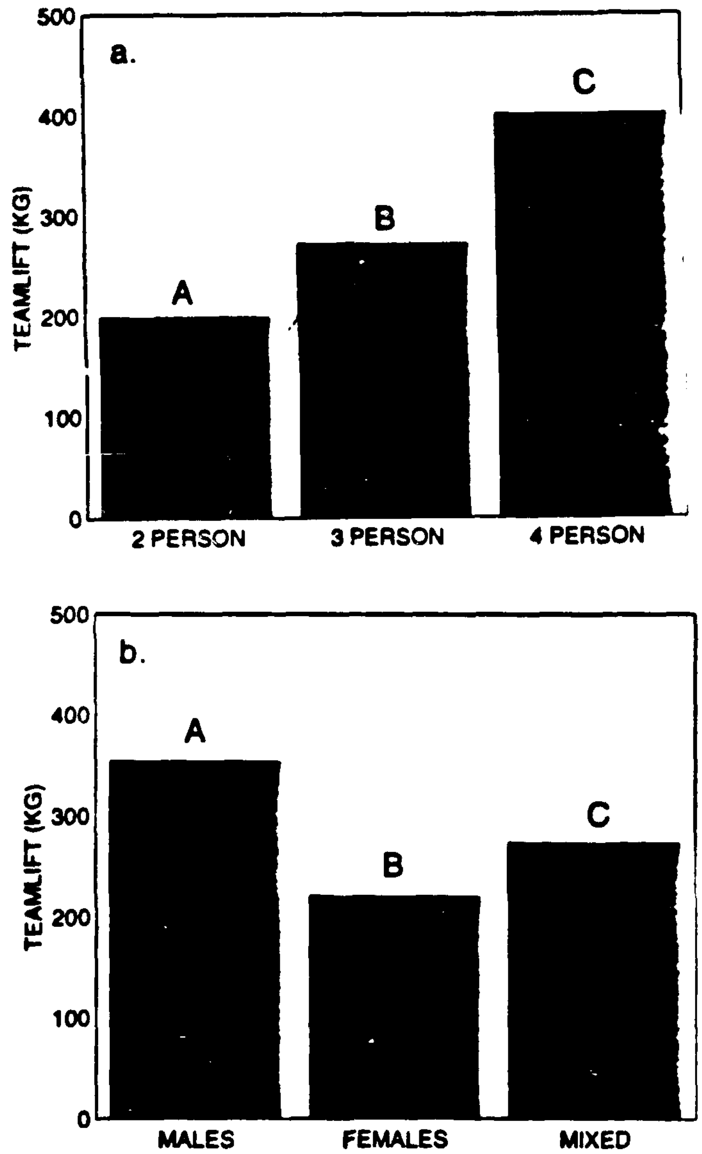
Table 4 contains the maximum team-lifting capacity values for the team sizes by gender. The three-person mixed-gender teams (one man with two women (n=18) and two men with one woman (n=18)) were combined for this analysis. A two-way analysis of variance revealed significant differences ($p<.01$) in the load lifted for team size, team gender and the interaction. Based on Tukey's HSD post-hoc tests for the main effects, there were significant differences between all team sizes (two, three and four, $p<.01$), between all gender groupings (male, female and mixed, $p<.01$), and between most gender by team size combinations ($p<.01$). The main effects of team size and gender are illustrated in Figure 7 (a and b).

Table 4. Maximum team-lifting capacity in two-, three- and four-person teams ($\bar{X} \pm SD$, (n)).

Team size	Men	Women	Mixed-gender
Two-person	252.9 ± 32.8^{a} (26)	155.8 ± 15.7^{b} (24)	$183.5 \pm 24.1^{b\,c}$ (25)
Three-person	345.1 ± 39.5^{d} (18)	214.6 ± 17.6^{c} (18)	262.3 ± 33.5^{a} (36)
Four-person	493.2 ± 65.3^{e} (20)	307.7 ± 31.4^{f} (19)	397.3 ± 37.1^{g} (21)

$^{a-g}$ Means with same letter are not significantly different from one another, all others are significantly different ($p<.05$).

Figure 7. Results of post-hoc analysis for a) team size and b) gender effects for team-lifting capacity.



In two-person teams two men lifted the heaviest absolute load, one man and one woman lifted 27% less than two men, and two women lifted 38% less than two men. There was no significant difference in team-lifting capacity between female and mixed-gender two-person teams. The male-to-female ratio for two-person teams was .62. In three-person teams, three men lifted the heaviest load, mixed-gender teams (two men with one woman combined with one man with two women) lifted 24% less, and three women lifted 38% less. The male-to-female ratio for three-person team lifting was .62. In four-person teams four men lifted the heaviest load, mixed-gender teams lifted 19.4% less, and four women lifted 37.6% less than four men. The female-to-male ratio for lifting in four-person teams was .62. There was a significant difference between the team lift and the sum of the individual dead lift scores for all team size and gender combinations ($p<.01$).

PERCENT SUM

Team-lifting capacity as a percentage of the sum of individual 1RM dead lift strength was calculated as follows:

$$\% \text{ sum} = (\text{team lift/sum individual lifts}) \times 100 \quad (1)$$

Table 5 contains the % sum for two-, three-, and four-person teams by gender group. Two-way analysis of variance resulted in a significant gender effect for % sum, but no team size or interaction effects. Significant differences between teams of men and women ($p<.05$), and between single-gender teams and mixed-gender teams ($p<.01$) were found using a post-hoc Tukey test.

Since four-person teams were made up of previously determined two-person teams, the % sum lifted in four-person teams was also determined using the sum of the two, two-person lifts as the standard:

$$\% \text{ sum}_{2P+2P} = (\text{4P team lift/(2P + 2P team lifts)} \times 100). \quad (2)$$

The % sum $_{2P+2P}$ was 98.6% for teams of four women, 96.5% for teams of four men, and 107.8% for teams of two men and two women. The % sum $_{2P+2P}$ for

Table 5. Percent sum of individual lifts represented by the team-lifting capacity in two-, three- and four-person teams ($\bar{X} \pm$ SD, (n)).

Team size	Men	Women	Mixed-gender
Two-Person	89.8 ± 8.9	91.9 ± 7.6	79.7 ± 11.4
	(26)	(24)	(25)
Three-Person	85.0 ± 7.6	90.9 ± 5.9	78.5 ± 8.5
	(18)	(18)	(36)
Four-Person	86.0 ± 9.7	90.3 ± 6.6	83.7 ± 5.6
	(20)	(19)	(21)

single-gender teams was significantly less than that of mixed-gender teams ($p<.01$).

THREE-PERSON TEAM-LIFTING ANALYSIS

An additional one-way analysis of variance was performed for three-person teams, because there were four gender groupings: all men, all women, two men with one woman (2M&1W), and one man with two women (1M&2W). Table 6 contains the maximum team-lifting capacity and % sum for three-person teams for each of four gender combinations. The absolute load lifted decreased as the number of men in the team decreased, three men lifted the heaviest load, 2M&1W lifted 18.8% less ($p<.01$), 1M&2W lifted 29.2% less ($p<.01$), and three women lifted 37.8% less ($p<.01$) than 3 men. All gender groups were significantly different from each other in terms of absolute load lifted ($p<.05$).

The % sum for 2M&1W teams (74.4%) was lower than for any other gender combination ($p<.01$). Teams of three women had a significantly greater % sum (91.0%) than 1M&2W teams (82.7%, $p<.01$). The % sum for teams of three men (85.0%) was not significantly different from teams of three women or from teams

Table 6. Percentage sum for three-person team lifting.

	3 men	3 women	1M&2W	2M&1W
n	18	18	18	18
Team lift (kg)[1]	345.1	214.6	244.3	280.3
%Sum	85.0	91.0	82.7[2]	74.4[3]

[1] All gender groups significantly different ($p<.01$), except 3 men vs 2 men & 1 woman ($p<.05$).
[2] Significantly different from teams of three women ($p<.01$).
[3] Significantly different from all other gender groups ($p<.01$).

of 1M&2W.

EFFECT OF WEAKEST TEAM MEMBER

It was hypothesized that the team-lifting capacity would be determined by the weakest individual within the team. In order to test this theory, the percentage difference between the team lift and the smallest individual dead lift among the team members multiplied by the number of lifters was calculated:

$$\%\text{difference} = \frac{\text{team lift} - (\text{n} \times \text{small dead lift})}{\text{team lift}} \times 100 \qquad (3)$$

These results are listed in Table 7. There were significant gender, team size and interaction effects for percentage difference, and the overall mean was significantly different from zero ($p<.01$). Male and female teams had a significantly lower percentage difference than mixed-gender teams ($p<.01$), as illustrated in Figure 8a. The percentage difference for two-person lifting was significantly less than for three-person ($p<.05$) and four-person lifting ($p<.01$), as illustrated in Figure 8b. As shown in Figure 9a, post-hoc analysis of the team size by gender interaction revealed that four-person mixed-gender teams had a significantly greater percentage difference than two- or three-person teams ($p<.05$). Figure 9b illustrates that three-person mixed-gender teams had a significantly greater percentage difference than three-person female teams ($p<.05$). As shown in

Figure 9c, the percentage difference for four-person mixed-gender teams was significantly greater than all other team size combinations ($p<.01$). The means for team-lifting capacity and the corresponding team size multiplied by the smallest dead lift are Illustrated by team size and gender in Figure 10 a-c. The values for both variables by team size and gender are listed in the Appendix in Table A1. The percentage difference was within ± 3% of the team lift for all single-gender teams, and ranged from -6% to -21% for mixed-gender teams.

Table 7. Percentage difference between the team lift and the smallest dead lift multiplied by the number of lifters[1].

Team size	Men	Women	Mixed-gender
Two-person	-2.6 ± 9.1	-1.5 ± 9.5	6.2 ± 7.1
Three-person	3.0 ± 10.4	-0.6 ± 10.9	9.6 ± 10.9[2]
Four-person	-0.9 ± 10.3	2.0 ± 7.5	20.8 ± 8.3[3]

[1] % difference=(team lift-(n x smallest dead lift))÷ team lift) x 100)
[2] Significantly different from women three-person teams ($p<.05$).
[3] Significantly different from all other team size by gender groups ($p<.01$).

TEAM COHESIVENESS

All data thus far have been reported for the team collectively. The team cohesion, RPE, and pain, soreness and discomfort data will be reported by gender of the individual and by gender of the team. For example, a team cohesiveness score for **women** lifting with men was reported by **women**. The team cohesiveness score for **men** lifting with women was reported by **men**. The unique gender combinations found in three-person teams will be addressed in a later section.

The means and standard deviations for team cohesiveness reported by the four gender combinations are listed in Table 8. There were significant gender ($p<.05$) and interaction effects ($p<.05$), and Tukey post-hoc tests were conducted to determine the location of the differences. As shown in Figure 11a, women in

Figure 8. Results of pos' hoc analysis for a) team size and b) gender effects for percentage difference be'ween the team lift and the samllest dead lift multiplied by the number of lifters.

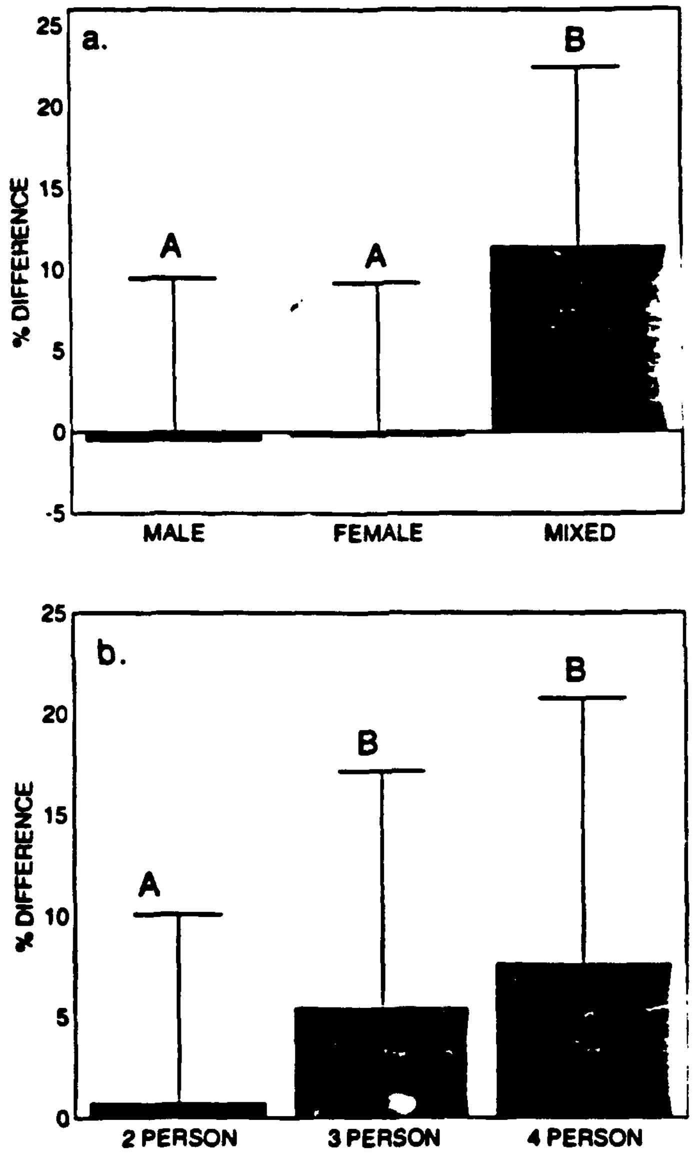


Figure 9. Results of post-hoc analysis of significant team size by gender interaction effect for percentage difference a) team size within mixed gender, b) gender within three-person teams, c) gender within four person teams. Different letters represent significant differences.

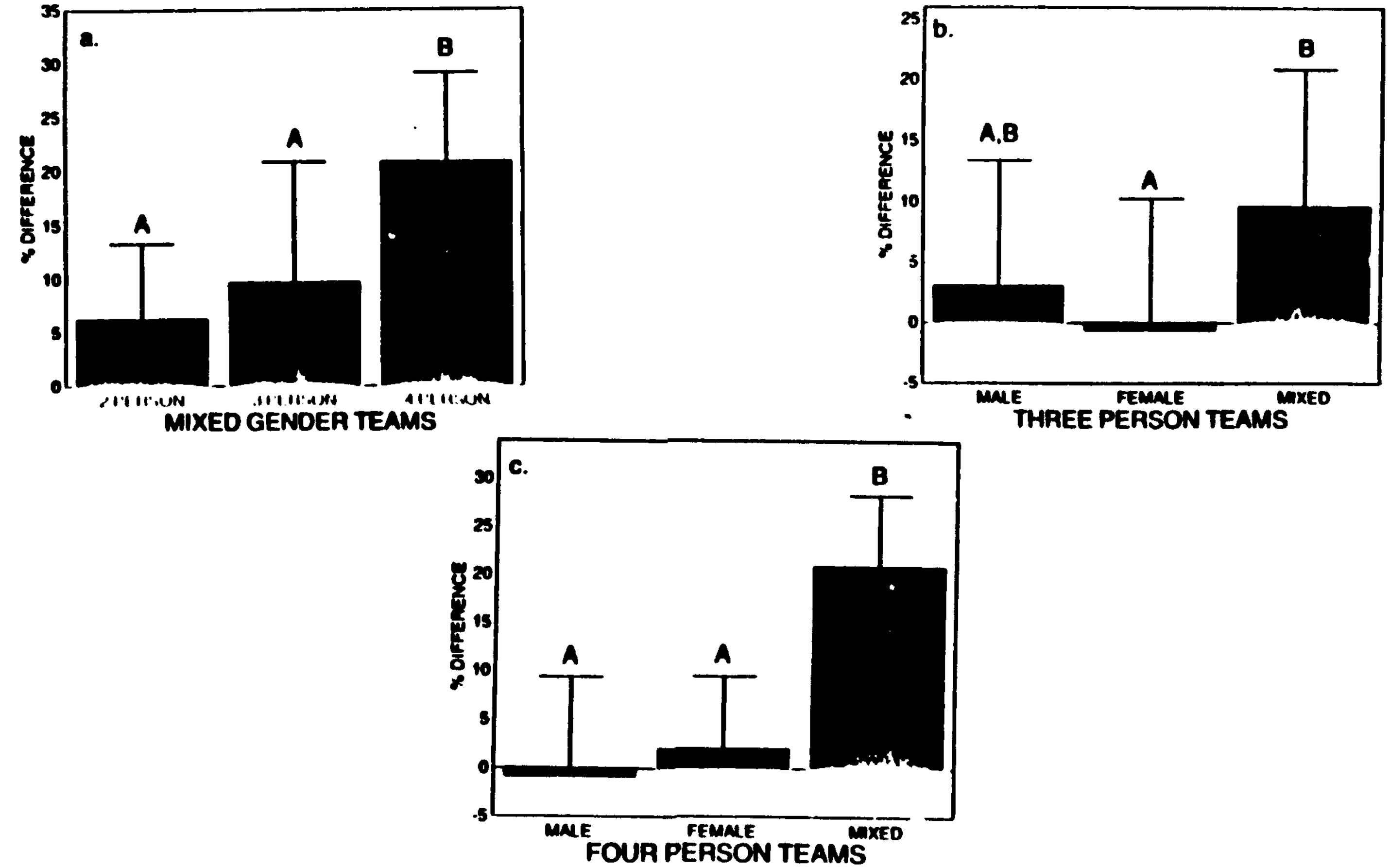


Figure 10. Team-lifting capacity and team size multiplied by the smallest dead lift for each team size and gender.

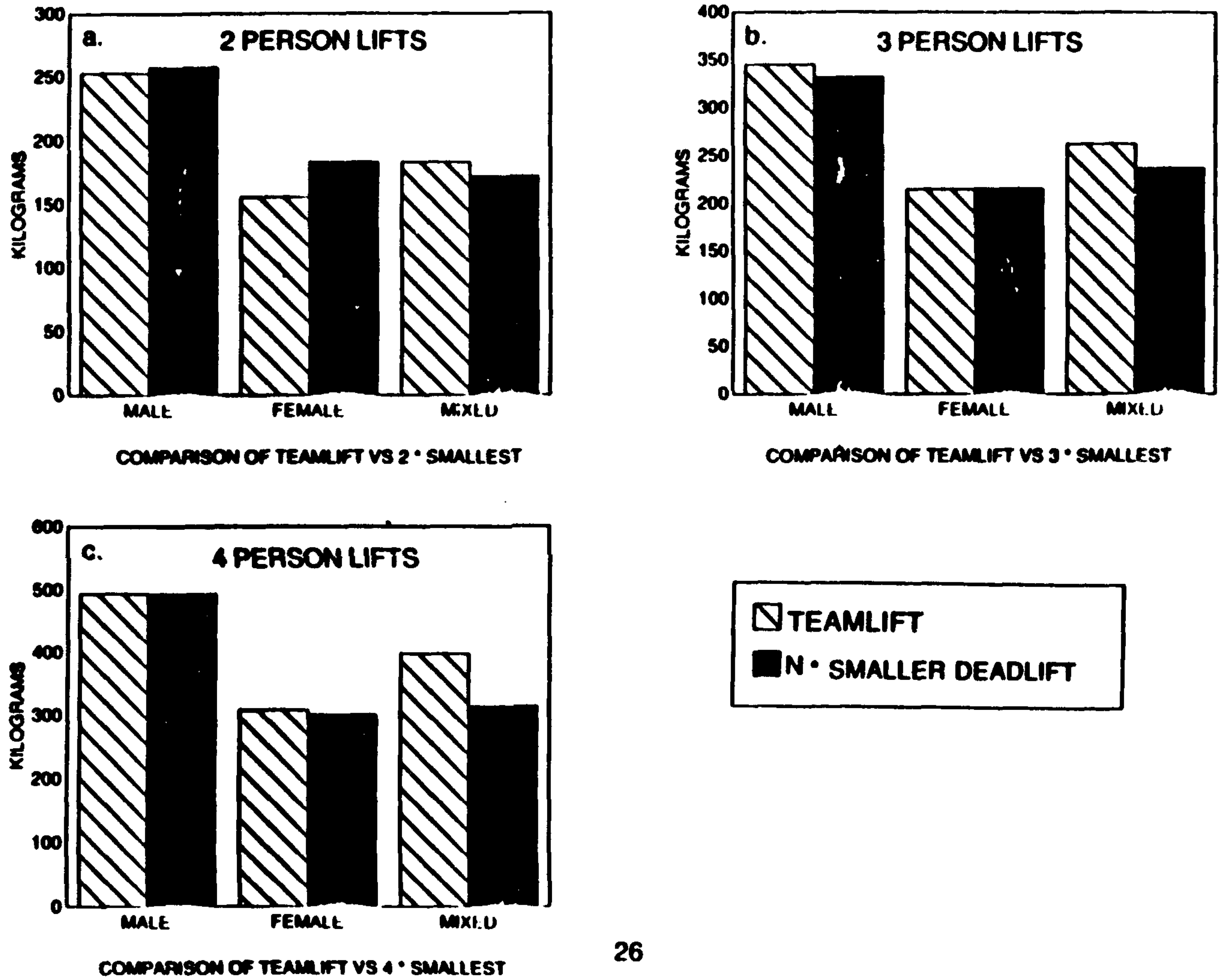
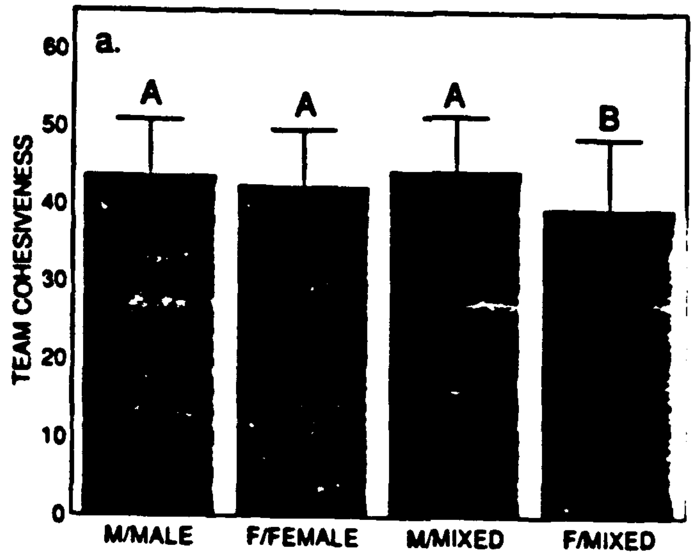
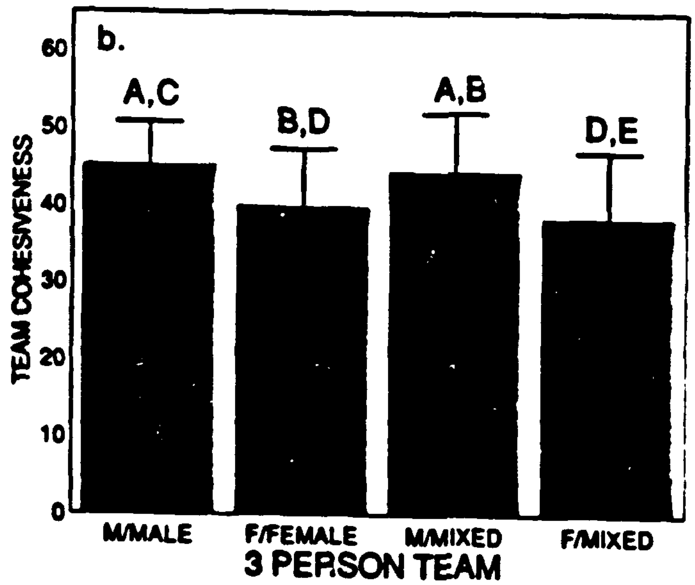


Figure 11. Results of post-hoc analysis of a) gender and b) team size by gender interaction effects for team cohesion. Different letter represent significant difference between means ($p<.05$).





mixed-gender teams exhibited lower team cohesion scores than any other gender team (p<.05). The differences that will be discussed for the interaction effect are those across genders within team sizes, and those within genders across team sizes. As shown in Figure 11b, post-hoc analysis revealed that women working in single- and mixed-gender three-person teams had significantly lower team cohesion scores than men in single-gender teams and women in mixed-gender three-person teams had lower team cohesion than men in mixed-gender three-person teams (p<.05).

Table 8. Team cohesiveness for two-, three- and four-person team lifting ($\bar{X}$, (SD)).

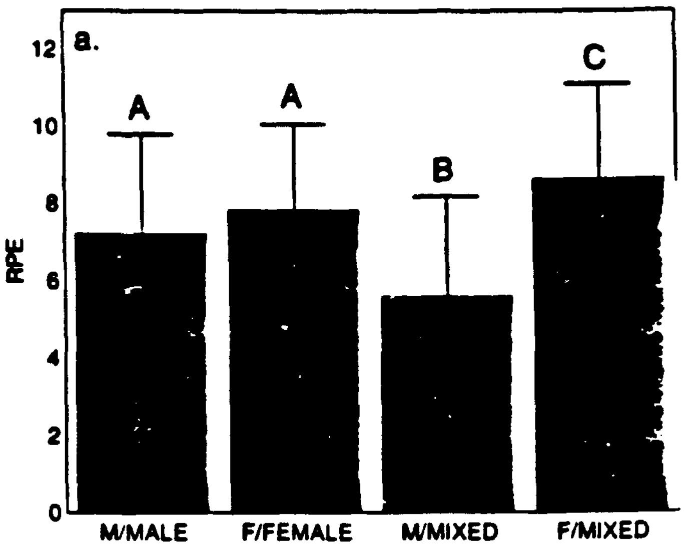
Team size	Man w/men	Woman w/women	Man w/mixed-gender	Woman w/ mixed-gender
Two-person	41.9 (9.2)	44.1 (7.6)	44.9 (7.4)	42.4 (10.0)
Three-person	45.1 (5.7)	39.8 (7.6[1])	44.3 (7.8[2])	38.3 (8.7[1])
Four-person	44.2 (6.5)	43.1 (6.9)	44.5 (5.9)	39.9 (9.4)

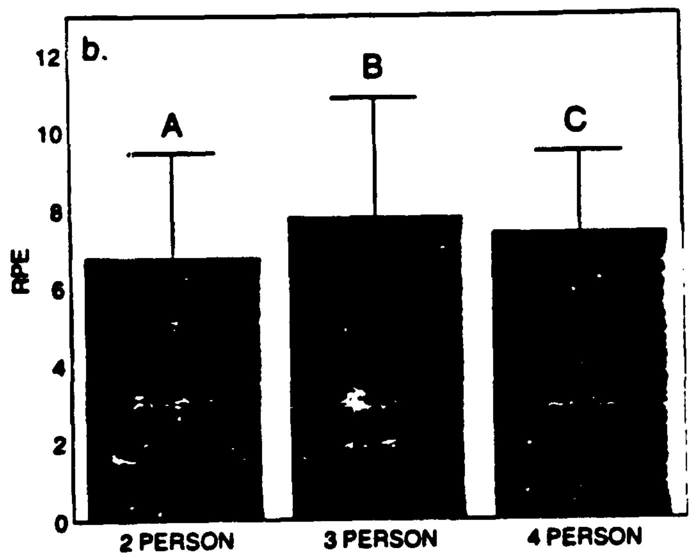
[1] Significantly different from three-person man w/men (p<.05).
[2] Significantly different from three-person woman w/mixed-gender (p<.05).

RATINGS OF PERCEIVED EXERTION

The means and standard deviations for the RPE data are listed in Table 9. Analysis of variance of the RPE produced significant gender, team size and interaction effects (p<.01). The RPE reported by women in mixed-gender teams was significantly greater than that reported by any other gender combination, as shown in Figure 12a. The lowest RPE was that of men in mixed-gender teams and this was significantly different (p<.01) from all other gender combinations. Figure 12b contains the means for RPE reported by two-person teams which was

Figure 12. Results of post-hoc analysis of a) gender and b) team size effects for RPE. Different letter represent significant difference between means ($p<.05$).





significantly less that reported by three- ($p<.01$) and four-person teams ($p<.05$). The differences that will be discussed for the interaction effect are those across genders within team sizes, and those within genders across team sizes. These are illustrated in Figure 13a-d. Within two-person teams, males lifting in mixed-gender teams reported a lower RPE than any other gender combination (Figure 13a, $p<.05$). Within three-person teams, the RPE of women in mixed-gender teams was significantly greater than men in single- or mixed-gender teams (Figure 13b, $p<.01$). There were no gender differences in RPE within four-person teams. There were no differences in RPE across team sizes for single-gender teams. The RPE for men lifting in mixed-gender two-person teams was significantly lower than for those in mixed-gender three- and four-person teams (Figure 13c, $p<.01$). For women in mixed-gender teams, RPE for three-person teams was significantly greater than four-person teams (Figure 13d, $p<.01$).

Table 9. RPE for two-, three- and four-person teams ($\bar{X}$ (SD)).

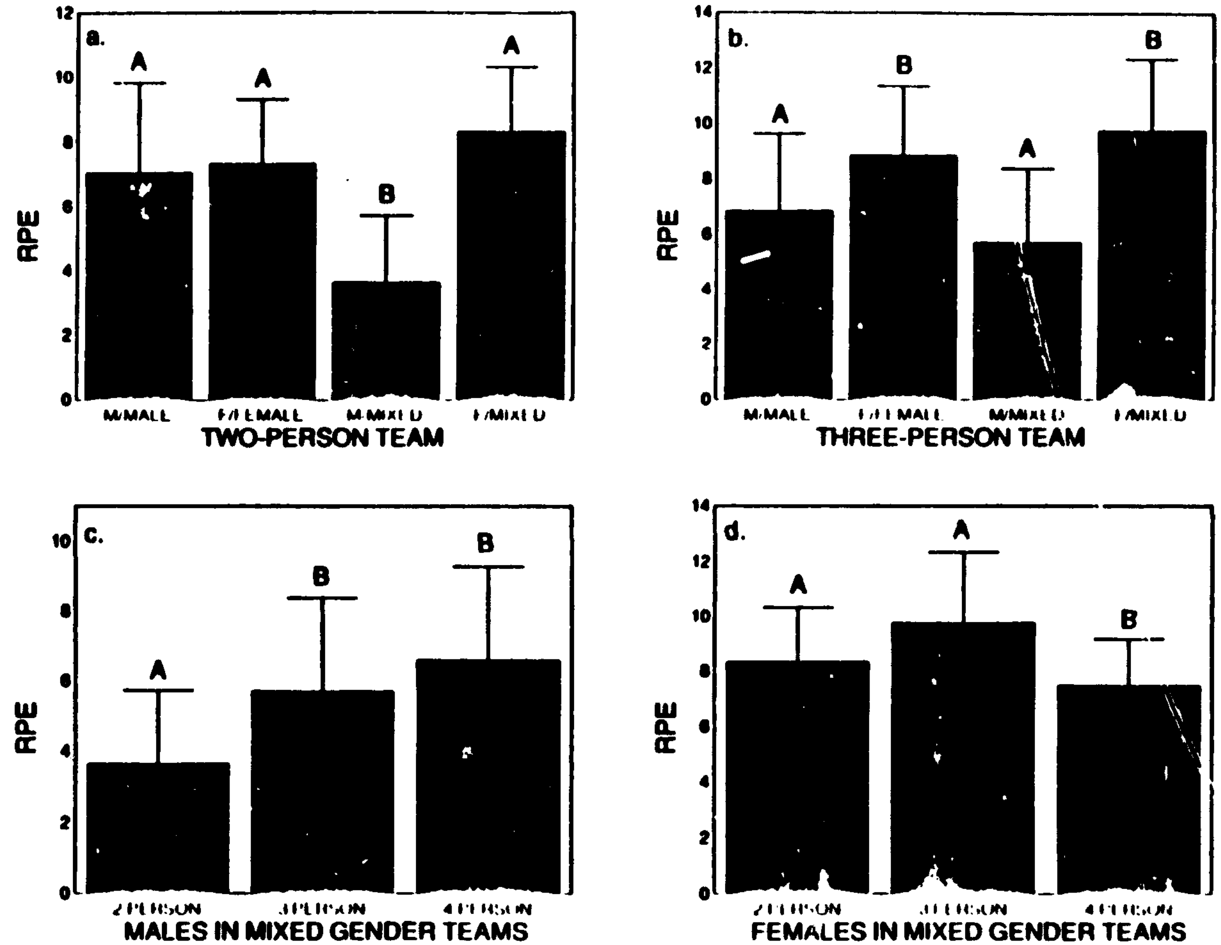
Team size	Man w/men	Woman w/women	Man w/mixed-gender	Woman w/ mixed-gender
Two-person	7.0 (2.8)	7.3 (2.0)	3.6 (2.1[1])	8.3 (2.0)
Three-person	6.8 (2.8[2])	8.8 (2.5[3])	5.7 (2.7[2])	9.7 (2.6)
Four-person	7.6 (2.3)	7.5 (2.0)	6.6 (2.7)	7.5 (1.7[2])

[1] Significantly different from all other means ($p<.01$).
[2] Significantly different from three-person woman w/men ($p<.01$).
[3] Significantly different from three-person man w/men and from three-person man w/women ($p<.01$).

PAIN, SORENESS AND DISCOMFORT QUESTIONNAIRES

Pain, soreness and discomfort questionnaires were administered before and after each lifting trial. The ratings were summed for a total pain, soreness and

Figure 13. Results of post-hoc analysis of significant team size by gender interaction for RPE. Different letter represent significant difference between means (p<.05).



discomfort score before and after lifting, and are listed in Table 10. A repeated measures two-way analysis of variance revealed significant effects for gender ($p<.05$), team size ($p<.01$) and pre- to post-lift (repeated measure). There was a significant increase in total pain, soreness and discomfort pre- to post-lifting ($p<.01$), but Tukey post-hoc tests did not support a significant difference between genders. Three-person teams reported higher levels of total pain, soreness and discomfort than two- or four-person teams ($p<.05$). The pre- to post-lift (repeated measures) by gender interaction was significant ($p<.01$). Post-hoc analysis revealed significant increases in total pain, soreness and discomfort pre- to post-lifting in men in single-gender teams ($p<.05$), women in single-gender teams ($p<.01$), and in women in mixed-gender teams ($p<.01$). There was no change pre- to post-lift in pain, soreness and discomfort in men lifting in mixed-gender teams. Post-hoc analysis of a significant pre- to post-lift (repeated measures) by team size interaction revealed that three-person teams had higher ratings of pain, soreness and discomfort than two- or four-person teams before and after the lift ($p<.01$). All three team sizes increased in pain, soreness and discomfort pre- to post-lift ($p<.05$).

Table 10. Total pain, soreness and discomfort ratings for two-, three- and four person teams before and after lifting.

	Man w/men	Man w/ mixed	Woman w/women	Woman w/mixed
Two-person pre	3.02	0.88	3.02	3.22
post	4.22	1.08	3.94	4.92
Three-person pre	4.03	5.31	5.63	4.13
post	4.97	5.75	8.59	8.66
Four-person pre	2.56	0.80	3.35	2.95
post	3.66	1.71	4.76	4.66

The pain, soreness and discomfort reported for the individual body parts are listed in the appendix in Tables A2 and A3 for the front and back of the body, respectively. The increases in scores for individual body parts were of a very small magnitude, typically less than one point on a scale of zero to five. The body parts with significant main effects (team size, gender and pre- to post-lift) are listed in Table 11. There were significant increases pre- to post-lift in several body parts, including the neck, shoulders, hands, upper-, mid- and lower-back. Significant gender effects were found for the hands, hips, the back of the neck and the mid-back ($p<.05$). With the exception of mid-back, the women tended to report higher levels of pain, soreness and discomfort. Where significant differences were found for team size, the three-person team was significantly greater than two- and/or four-person teams.

ANALYSES FOR THREE-PERSON TEAMS

In three-person teams there were six gender combinations for the subjective data: 1) a man with two men, 2) a man with one woman and one man, 3) a man with two women, 4) a woman with two women, 5) a woman with one man and one women and 6) a woman with two men. Separate analyses were conducted for team cohesiveness, RPE and pain, soreness and discomfort. The RPE and team cohesiveness scores for the six gender combinations are listed in Table 12.

Table 11. Pain, soreness and discomfort significant main effects from repeated measures analysis of variance, and post-hoc Tukey test results.

TEAM SIZE

Front of body	2P (1)	3P (2)	4P (3)	Post-hoc Tukey
1. neck (p<.01)	.01	.28	.02	2P & 4P vs 3P**
2. shoulder (p<.01)	.08	.17	.07	NSD[1]
3. hand (p<.01)	.05	.14	.03	3P vs 4P *

Back of body	2P	3P	4P	Post-hoc Tukey
1. neck (p<.01)	.20	.49	.15	2P & 4P vs 3P**
2. shoulder (p<.05)	.16	.24	.14	NSD
3. upper back (p<.01)	.28	.53	.26	3P vs 4P*
4. mid-back (p<.01)	.50	1.04	.48	2P & 4P vs 3P**
5. low-back (p<.01)	.49	.94	.38	2P & 4P vs 3P**
6. hamstring (p<.05)	.22	.38	.25	NSD

GENDER

Front of body	M/men[2] (1)	M/mix[2] (2)	W/women[2] (3)	W/mix[2] (4)	Post-hoc Tukey
1. hand	.02	.01	.14	.11	1&2 vs 3*
2. hips	.07	.00	.13	.13	2 vs 3&4**

Back of body	M/men[2]	M/mix[2]	W/women[2]	W/mix[2]	Post-hoc Tukey
1. neck	.17	.12	.33	.45	2 vs 4*
2. mid-back	.74	.87	.51	.53	2 vs 3*

**(p<.01), *(p<.05).

Table 11. Pain, soreness and discomfort significant main effects from repeated measures analysis of variance, and post-hoc Tukey test results (cont'd).

PRE- TO POST-LIFT CHANGES

Front of body	pre-lift	post-lift
1. neck (p<.01)	.07	.13
2. shoulder (p<.01)	.09	.12
3. hand (p<.01)	.03	.11
4. abdomen (p<.01)	.06	.10

Back of body	pre-lift	post-lift
1. neck (p<.05)	.24	.30
2. shoulder (p<.01)	.15	.20
3. forearm (p<.01)	.07	.11
4. hand (p<.01)	.03	.07
5. upper back (p<.01)	.30	.40
6. mid-back (p<.01)	.48	.85
7. low-back (p<.01)	.42	.75
8. foot-bottom (p<.01)	.02	.05

[1] NSD=no significant difference

[2] M/men= man with men; M/mix= man with mixed-gender; W/women= woman with women; W/mix= woman with mixed-gender.

*(p<.05), **(p<.01)

Team cohesiveness

The team cohesiveness score for women lifting with two men was significantly less than those reported by men in any gender combination (p<.05). The team cohesiveness score for women lifting with a woman and a man was

Table 12. Team cohesiveness survey (Team co.) and RPE for three-person lifting.

		Man(M) w/ 2M	M w/2 women(W)	M w/1M & 1W	Women w/2W	W w/2M	W w/1M & 1W
group		1	2	3	4	5	6
Team	$\bar{X}$	45.1	44.1	44.8	39.8	38.9[1]	38.0[2]
Co.	SD	5.7	8.4	6.8	7.6	9.6	8.2
RPE	$\bar{X}$	6.8[3]	5.6[4]	8.8	5.7[4]	9.9	9.7
	SD	2.8	3.3	2.5	2.5	2.6	2.7

[1] Significantly different from groups 2 and 3 ($p<.05$), and from group 1 ($p<.01$).
[2] Significantly different from groups 1 and 2 ($p<.05$).
[3] Significantly different from groups 5 and 6 ($p<.01$).
[4] Significantly different from groups 2, 5 and 6 ($p<.01$).

significantly less than that reported by men lifting with all men and men lifting with one man and one woman ($p<.05$). Women lifting with men reported lower team cohesiveness, but when men lifted with women the reverse was not true.

RPE

The RPE for men in an all male team was less than that for women lifting in mixed-gender teams ($p<.05$), but was not different than that for three women. Men lifting in mixed-gender teams reported lower RPEs than were reported by women ($p<.01$), regardless of the women's team gender composition.

Pain, Soreness and Discomfort

The total pain, soreness and discomfort data for three-person teams with six gender combinations are presented in Table 13. A repeated measures analysis of variance produced no significant gender effect, a significant increase pre- to post-lift ($p<.01$) and a significant interaction effect ($p<.01$). Examination of the interaction effect revealed that the only groups that increased ($p<.01$) in total pain, soreness and discomfort from pre- to post-lift were women lifting in mixed-gender

teams (women with two men, and women with one man and one woman). Men lifting in single-gender teams reported less pain, soreness and discomfort post-lift than women lifting in single-gender teams ($p<.05$) or women lifting with one man and one woman ($p<.01$). Men lifting with one man and one women reported less pain, soreness and discomfort than women lifting with one man and one women ($p<.01$).

Table 13. Total pain, soreness and discomfort ratings in three-person teams.

	Man(M) w/2M	Man w/2 women(W)	Man w/ 1M & 1W	Woman w/2W	Woman w/2M	W w/1M & 1W
pre- $\bar{X}$ (SD)	4.0 (4.7)	5.2 (3.9)	5.3 (5.8)	5.6 (9.2)	3.1[1] (4.7)	4.8[1] (7.3)
post $\bar{X}$ (SD)	5.0[2] (5.1)	6.5 (5.2)	5.5[3] (4.9)	5.6[3] (13.2)	7.1 (8.9)	9.2[3] (12.6)

[1] Significant difference pre- to post-lift ($p<.01$).
[2] Significantly different from W w/1M&1W ($p<.01$).
[3] Significantly different from male w/2M ($p<.05$).

CORRELATIONAL ANALYSES

The sum of strength measurements and body dimension variables of the team members was correlated with team-lifting capacity. In two-person teams, for example, the sum of the height of subjects one and two was correlated with the team lift for subjects one and two. For three- and four-person teams, the sum of the three or four individual scores was correlated with their team lift. The correlations for two-person teams are listed in Table 14. Team-lifting capacity of two men was significantly correlated with all measures of strength ($p<.01$), weight, and fat-free mass ($p<.05$). For two women, the strongest correlations with team-

lifting capacity were the sums of dead lift strengths (r=.73) and isometric lifting strengths (r=.60, p<.01). In two-person mixed-gender teams, the only significant correlation was with height (r=-.43, p<.05). When all two-person teams were included in the analysis, all variables were significantly correlated with team-lifting capacity (p<.01). This was true for all team sizes.

Table 14. Correlation of two-person team-lifting capacity with the sum of individual measures of strength, body size and anthropometric dimensions.

	men	women	mixed	all teams
Dead lift	.55**	.73**	.26	.85**
Incremental lift	.60**	.34	-.04	.82**
Upright pull	.74**	.60**	.17	.84**
Weight	.42*	.24	-.13	.69**
Height	.15	-.06	-.43*	.67**
Fat-free mass	.46*	.19	-.25	.78**
Trochanteric height	.19	-.03	-.21	.605
Sleeve outseam	.10	-.04	-.45*	.50**
Hand circumference	.21	-.20	-.18	.68**
Fist circumference	.21	.50*	.33	.81**
Grip diameter	-.03	.40	.01	.56**

*(p<.05), **(p<.01)

For two-person teams, the absolute value of the difference between the individuals' strength and body size was correlated with team-lifting capacity (Table 15). For example, the absolute value of the difference in height of subjects one and two was correlated with the team lift for subjects one and two. In single-gender teams, none of the difference scores were significantly correlated with team-lifting capacity. In mixed-gender teams, none of the strength differences were significantly correlated with team-lifting capacity. However, differences

between the weight (r=-.56), height (r=-.53) and fat-free mass (r=-.59) were all negatively correlated with team-lifting capacity (p<.01).

Table 15. Correlation between two-person team-lifting capacity and the absolute difference between the two individual scores.

difference	men	women	mixed-gender	all teams
Dead lift	.17	.34	-.35	-.23
Incremental lift	.15	.14	-.38	.01
Upright pull	.01	.27	-.38	.02
Weight	.31	.17	-.56**	-.02
Height	.31	-.13	-.53**	-.01
Fat-free mass	.23	.15	-.59**	-.05

**(p<.01)

Two-person team-lifting capacity was correlated with the lesser of the two team members' individual strength and body size measurements (Table 16). All measures of strength were significantly correlated with team-lifting capacity in teams of two men (p<.01). The smaller individual dead lift (p<.01) and smaller isometric lift (p<.05) were correlated with team-lifting capacity in women and mixed-gender two-person teams.

The correlations between the sum of descriptive variables and three-person team-lifting capacity are listed in Table 17. For teams of three men and teams of one man and two women, all measures of strength were significantly correlated with team-lifting capacity (p<.01), as were body weight (p<.01) and fat-free mass (p<.05). For three women and teams of two men and one woman dead lift, incremental lift and fat-free mass were all significantly correlated with team-lifting capacity (p<.05).

Table 16. Correlations between two-person team-lifting capacity and the smaller of the individual scores for each variable.

	men	women	mixed	all teams
Dead lift	.78**	.59**	.88**	.93**
Incremental lift	.51**	.27	.37	.86**
Upright pull	.73**	.42*	.57**	.88**
Weight	.32	.15	.41*	.75**
Height	-.04	.01	.08	.68**
Fat-free mass	.32	.39	.41	.82**

*(p<.05), **(p<.01)

The correlations between the sum of descriptive variables and four-person team-lifting capacity are listed in Table 18. In teams of four persons, the sum of dead lift strength was significantly correlated with team-lifting capacity for all gender teams ($p<.05$). Body weight and fat-free mass were significantly correlated with team-lifting capacity in single-gender teams ($p<.05$). Incremental lift was significantly correlated with team-lifting capacity in mixed-gender teams ($p<.01$).

Multiple regression equations were developed for each team size using dummy variables for gender. These equations are listed in Table 19. The R^2 ranged from .90 for two-person teams to .83 for three-person teams. The sum of the individual dead lift strength and the smallest dead lift were the best predictors of team-lifting capacity. The standard error of the estimate represented 8-9% of the overall mean for team-lifting capacity.

Table 17. Correlation between three-person team-lifting capacity and the sum of individual measures of strength, body size and anthropometric dimensions.

	men	women	1 man & 2 women	2 men & 1 woman	all teams
Dead lift	.63**	.64**	.51*	.54*	.88**
Incremental lift	.73**	.53*	.63**	.40	.89**
Upright pull	.70**	-.06	.61**	.41	.86**
Weight	.64**	.37	.59**	.42	.74**
Height	.18	.12	.19	.30	.80**
Fat-free mass	.66*	.60**	.66**	.62**	.90**
Trochanteric height	.14	.41	.10	.21	.77**
Sleeve outseam	-.44	.11	-.15	-.24	.53**
Hand circumference	.27	.51*	.55*	.52*	.86**
Fist circumference	.35	.66**	.55*	.56*	.87**
Grip diameter	-.17	.40	-.36	.31	.61**

* (p<.05), ** (p<.01)

Table 18. Correlation between four-person team-lifting capacity and the sum of individual measures of strength, body size and anthropometric dimensions.

	men	women	mixed	all teams
Dead lift	.47*	.64**	.64**	.89**
Incremental lift	.43*	.31	.57**	.88**
Upright pull	.50*	.48*	.74**	.90**
Body weight	.48*	.46*	.17	.81**
Height	.34	.17	-.07	.81**
Fat-free mass	.47*	.19	.14	.87**
Trochanteric height	.45	.12	.23	.78**
Sleeve outseam	.37	-.01	-.21	.72**
Hand circumference	.48*	.48*	-.05	.81**
Fist circumference	.45	.31	.25	.86**
Grip diameter	.42	.52	.36	.76**

*($p<.05$), ** ($p<.01$)

Table 19. Regression equations for the prediction of maximum team-lifting capacity (kg).

Team Size	Regression Equation	R^2	SEE
Two-person[1]	MTL = 0.73 + 7.0(A) + 1.2(B) + 1.54(SM) + .2(TDL)	.90	16.0
Three-person[2]	MTL = 97.1 - 26.8(A) - 47.2(B) - 34.6(C) + .61(TDL)	.83	23.8
Four-person[3]	MTL = -47.6 - 76.4(A) - 16.7(B) + .5(TDL)	.86	33.7

MTL = maximum team lift (kg).
SM = smallest individual dead lift of team.
TDL = total of individual dead lifts for team.
[1] All male team (A = 0, B = 0); all female team (A = 0, B = 1); mixed team (A = 1, B = 0).
[2] All male team (A = 0, B = 0, C = 0); all female team (A = 1, B = 0, C = 0); 2 male and 1 female team (A = 0, B = 1, C = 0); 2 female and 1 male team (A = 0, B = 0, C = 1).
[3] All male team (A = 1, B = 0); all female team (A = 0, B = 1); 2 male and 2 female team (A = 0, B = 0).

DISCUSSION

A greater number of lifters resulted in a heavier load lifted, however, an increase in the number of lifters beyond two did not affect the amount lifted as a percentage of the sum of their individual lifts. This indicates that the ability to generate lifting force was not degraded by an increase in the number of persons lifting from two to three or four. This conflicts with previously published results for isometric and isokinetic lifting in teams of two and three persons. Karwowski and Mital (1986) and Karwowski and Pongpatanasuegsa (1988) reported a decrease in the % sum with an increase (from two to three persons) in the number of individuals performing an isokinetic or isometric lift.

The % sum reported here is similar to that for box lifting reported by Karwowski (1988). However, the quantities lifted were much greater than those reported by Karwowski (1988) who found a two-man lift of 105.7 kg and a two-woman lift of 75.7 kg compared to 252.9 kg and 155.8 kg for men and women, respectively, in the present study. This may be due to either the subject sample, the type of objects lifted or the lifting technique employed. As mentioned earlier, the female subjects were similar in incremental lifting strength to a large group of new female recruits, however the men were well above average. Both genders were in the 80th percentile for isometric lifting strength, and were not screened for previous weight-lifting experience. The weight-lifting devices used for this study did not have to be lifted above knuckle height, so little upper body strength was involved. The lift used by Karwowski (1988) required the box to be placed on a platform between wrist and waist height which would involve more of the upper body musculature.

Comparison of the results of Karwowski and colleagues (1986; 1988; 1988) with those of the present study are listed in Table 20. The % sums for isometric two- and three-person lifting were similar to those for two- and three-person isotonic lifting, with the exception of the two-woman isometric lift, which seemed lower. The % sum for isokinetic lifting was less than either isometric or isotonic lifting for both team sizes and genders.

Table 20. Comparison of % sum from present data for two- and three-person lifting with that of Karwowski and colleagues.

		Karwowski		Present study	
		men	women	men	women
Isotonic	Two- person	87.5	91.0	69.8	91.9
	Three-person			85.0	90.9
Isometric	Two-person	94.1	79.1		
	Three-person	88.6	87.0		
Isokinetic	Two-person	66.5	70.5		
	Three-person	60.3	72.8		

[1] (Karwowski, 1988; Karwowski & Mital, 1986; Karwowski & Pongpatanasuegsa, 1988)

The weakest individual determined the load in single-gender teams. The percentage difference between the team lift and the smallest dead lift multiplied by the number of lifters was close to zero in single-gender teams. This indicates that the weakest individual would have to lift their 1RM dead lift strength during the team lift if the weight were distributed equally. In mixed-gender teams the team lift was greater than the smallest dead lift multiplied by the team size, and this tendency increased with increasing team size. The percentage differences were significantly less for mixed-gender, two-person and three-person teams than for mixed-gender, four-person teams. Assuming that the load was distributed equally, this would require the weakest individual in the mixed-gender teams to lift more than their 1RM dead lift strength. It appears that the stronger individuals are able to take some of the load from the lower strength individuals, particularly in four-person mixed-gender teams. In two-and three-person teams, this would be more difficult due to the differences in height, weight, and fat-free mass of the people lifting as well as the configuration of the load. For example, if two men were lifting with one woman, the additional lifting force produced by the men would be unbalanced, due to the triangular shape of the lifting device. In four-person mixed-gender teams, the two men faced each other and the two women faced each other

across the square lifting device. The higher forces produced by the men would be applied more symmetrically than in a three-person team. This would result in a heavier lift, and thus a greater percentage difference between the team lift and four times the smallest dead lift. In two-person teams, where a strong individual was unable to make as great a difference in the team lift, the smallest dead lift was highly correlated ($p<.01$) with the team lift in all gender groupings. In addition, the greater the difference in height, weight and fat-free mass between the individuals lifting in mixed-gender, two-person teams, the lower the load lifted as a team.

The pain, soreness and discomfort scores, team cohesiveness score, and RPE are all subjective ratings which indicate how the individual felt about the lift. There were indications that some gender and team size combinations were preferred to others. Women seemed to prefer the single-gender teams to mixed-gender teams. The team cohesiveness scores for women in mixed-gender teams were lower than for any other gender combination. These may have been influenced by the women's perception of the degree to which they contributed to the effort. They may have felt they were not contributing equally to lifting the load, or were preventing the men in the team from lifting more weight. While the team cohesiveness was lower, the perception of effort (RPE) by women in mixed-gender teams was higher. Heavier loads were lifted in mixed-gender teams than in teams of all women, and this probably influenced the ratings of perceived exertion. There was no significant difference in RPE between teams of all men and teams of all women, indicating that single-gender teams perceived themselves to be working at similar intensities.

The pain, soreness and discomfort ratings were highest for three-person lifting. The only gender combination to report significant increases in pain, soreness and discomfort pre- to post-lift were women in mixed-gender teams when the three-person data were analyzed separately for the six gender combinations. The differences in height and lifting strength in three-person, mixed-gender teams may have caused an imbalance in the load distribution, which caused the shorter-stature, lower strength women to experience more pain, soreness and discomfort.

Teams of women lift significantly less weight than men or mixed-gender teams, but they work at a greater percentage of their maximal capacity. The % sum for teams of women was greater than for teams of men ($p<.05$) and both single-gender teams had a greater % sum than mixed-gender teams. For practical purposes, women lifting with men in three- or four-person teams allows the team to accomplish a heavier lift than an all woman team. However, if the objective were to have each person lifting to their maximum capacity, with the most positive subjective perceptions of pain, soreness and discomfort, team cohesion and effort, then single-gender teams are superior.

Military Standard 1472D (1989) provides guidelines for the design of equipment. It states that objects to be lifted infrequently by one man from floor to 36" should weigh no more than 39.5 kg and for one woman no more than 20 kg. These figures are doubled for two-person lifting (79 kg for men, 40 kg for women or mixed-gender team lifts), and 75% of the one person limit is added for each person added to the team after two. The subjects in this study were somewhat stronger than the average soldier, however, the actual team lifts were 3.17 to 5.68 times greater than the recommended weight limit. The percentages of the one-repetition maximum for one-, two-, three- and four-person lifting represented by the Military Standard are listed in Table 21 (%=Military Standard ÷ load lifted x 100). The standard represents 28-32% of the male team-lifting capacity, 23-26% of the female team-lifting capacity and 18-22% of the mixed-gender team-lifting capacity. The values for maximal team lift and Military Standard recommendations are shown in Figure 14a-d for individual dead lift, and two-, three- and four-person team lifting. When compared to Karwowski's (1988) data for two-person box lifting, the standards represent 75% of what two men lifted, and 52% of what two women lifted.

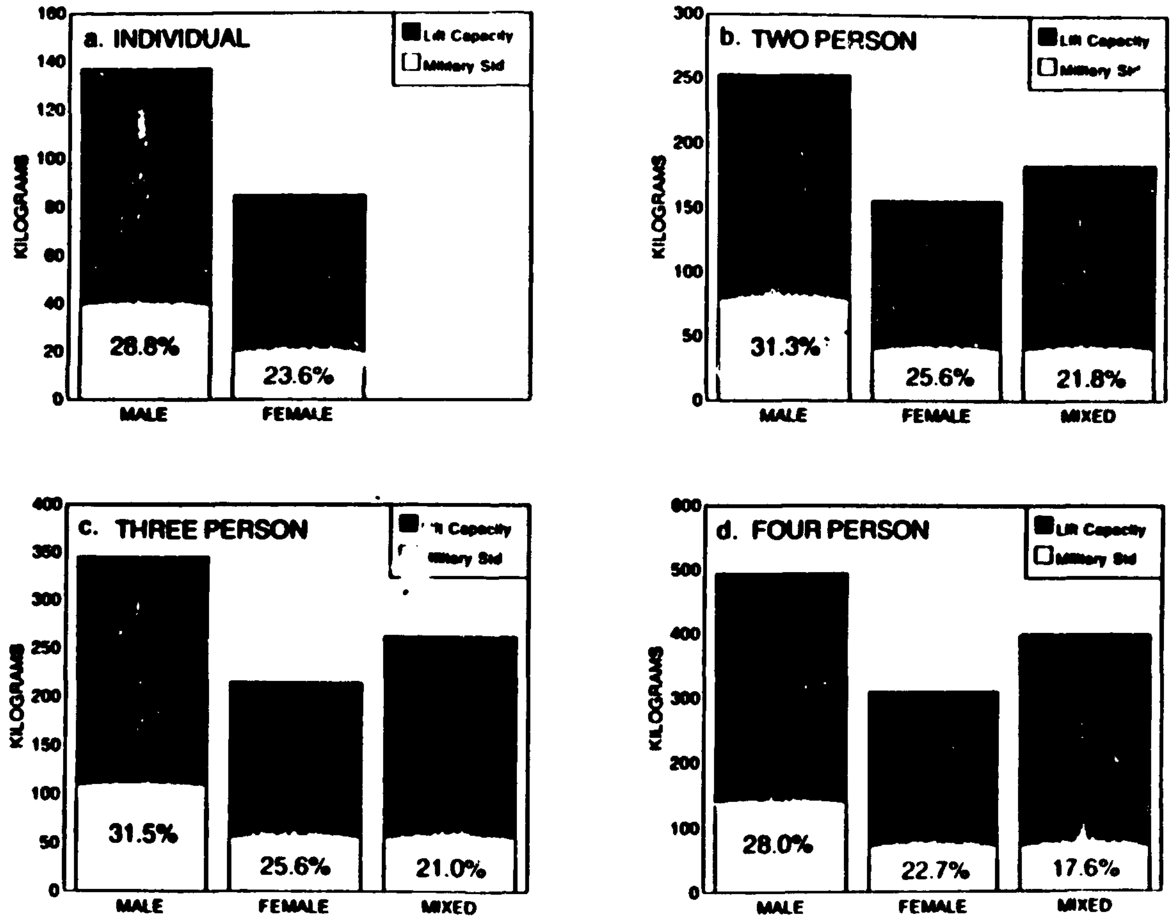
Military Standard 1472D (1989) appears to offer safe, conservative recommendations for design limits, but the recommendations are the same for mixed-gender and all women teams. While this may be appropriate for two-person teams, this study has shown that mixed-gender teams lift significantly more than

Table 21. Military Standard 1472D as a percentage of maximum-lifting capacity for individuals, and two-, three- and four-person teams.

team size	men	women	mixed-gender
1	28.8	23.6	NA
1[1]	66.9	47.6	NA
2	31.3	25.6	21.8
2[1]	75.2	52.4	-
3	31.5	25.6	21.0
4	28.0	22.7	17.6

[1] Data from Karwowski, 1988, all else from current study.

Figure 14. Percentage of team-lifting capacity represented by Military Standard 1472D recommendations for a) individual lifts, b) two-person team lifting, c) three-person team lifting and d) four-person team lifting.



3. The decrease in lifting potential (represented by the %sum) that occurs when an individual lifts in a two-person team is not affected by further increases in team size.

4. In single-gender teams, the weakest individual determines the load.

5. In mixed-gender teams, the stronger individuals enable the weaker individuals to lift a heavier load.

6. Single gender teams of men and women perceived themselves to be working at the same level of effort (RPE).

7. Women lifted heavier loads and perceived their effort to be greater in mixed-gender teams.

8. The greatest pain, soreness and discomfort was reported by women in three-person, mixed-gender teams.

9. Military Standard 1472D recommendations for lifting are well within the capabilities of these subjects.

10. The limits set by Military Standard 1472D represent a higher percentage of men's lifting capacity (28-32%) than women's (23-26%) or mixed-gender teams (18-22%).

RECOMMENDATIONS

1. Single gender teams should be used to optimize individual lifting potential.

2. To lift the heaviest absolute loads, maximize the number of lifters and the number of male team members.

3. Military Standard 1472D should be adjusted to represent equivalent percentages of these population norms. A limit of 40% of the population one-repetition-maximum seems reasonable.

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APPENDIX

TEAM COHESIVENESS SURVEY Date:______________

Team members (SUBJECT NUMBERS) List yourself first:

______________________ ______________________

Please read each of the following statements about your team. Answer to what degree the statement describes your feeling toward your partner by using the scale below and writing the appropriate number in the blank before each statement.

STRONGLY DISAGREE	SOMEWHAT DISAGREE	NEITHER AGREE NOR DISAGREE	SOMEWHAT AGREE	STRONGLY AGREE
1	2	3	4	5

1.______ My contribution to this team is valued by my teammate.

2.______ I like working in this team.

3.______ I feel that I am an accepted member of this team.

4.______ I have confidence in the capabilities of my teammate.

5.______ I feel proud to be a member of this team.

6.______ My teammate makes me feel significant and worthwhile.

7.______ I believe our team works well together.

8.______ I think this team could accomplish a lot if we were assigned to work together.

9.______ I want to continue to be part of this team.

10._____ If I had to go into combat, I would want to go and work with this teammate.

____________ Total Score

SORENESS, PAIN AND DISCOMFORT QUESTIONNAIRE

INSTRUCTIONS: Rate the degree of soreness, pain or discomfort that you are currently feeling for body parts 1 - 11. Do so fc the front and the back of the body.

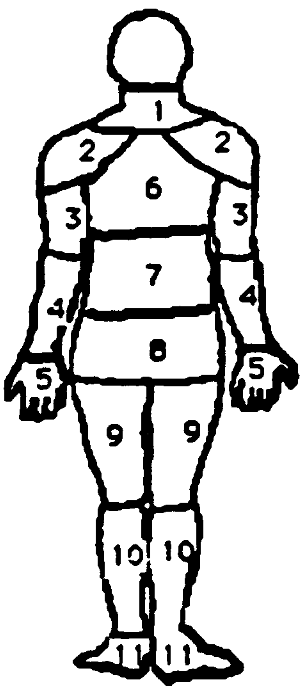
Start Time: AM PM

Subject #
and Name:

Date:

Subject #		Date				LIFT TYPE	
0	0	0	0	0	0	Single	
1	1	1	1	1	1		All Female
2	2	2	2	2	2	Double	
3	3	3	3	3	3		All Male
4	4	4	4	4	4	Quad	
5	5	5	5	5	5		Mixed Team
6	6	6	6	6	6	Triple	
7	7	7	7	7	7		
8	8	8	8	8	8		
9	9	9	9	9	9		

PLEASE USE A #2 PENCIL



FRONT OF BODY

	1	2	3	4	5	6	7	8	9	10	11
NONE											
VERY SLIGHT											
MILD											
MODERATE											
SEVERE											
EXTREME											

BACK OF BODY

	1	2	3	4	5	6	7	8	9	10	11
NONE											
VERY SLIGHT											
MILD											
MODERATE											
SEVERE											
EXTREME											

Rating of Perceived Exertion
(Category-Ratio Scale)

0	Nothing at all	
0.5	Very, very weak	(Just noticeable)
1	Very weak	
2	Weak	
3	Moderate	
4	Somewhat strong	
5	Strong	(Heavy)
6		
7	Very strong	
8		
9		
10	Very, very strong	(almost max)
•	Maximal	

Table A1. Comparison of team-lifting capacity to the smallest dead lift (DL) of the team times the number of team members

	Men	Women	Mixed-gender 2W&1M- 3P only	1W & 2M 3P only
Two x smaller DL	257.5 ± 24.7	157.5 ± 15.9	172.0 ± 25.4	
Two-person team lift	252.9 ± 32.8	155.8 ± 15.7	183.5 ± 24.1	
Three x smallest DL	331.8 ± 28.7	215.4 ± 25.6	223.7 ± 32.3	247.5 ± 24.7
Three-person team lift	345.1 ± 39.5	214.6 ± 17.6	244.3 ± 4.5	280.3 ± 35.4
Four x smallest DL	492.0 ± 29.3	300.0 ± 23.1	312.9 ± 30.4	
Four-person team lift	493.2 ± 65.3	307.7 ± 31.4	397.3 ± 37.1	

Table A2. Pain, soreness and discomfort for the front of the body pre- to post-lift in teams of two-, three- and four-persons.(The initial code M or F indicated the gender of the respondent, the code following the slash indicates the gender of the other team members: M=male, F=female, mix=mixed-gender team)

Front	Two-person				Three-person				Four-person			
	M/M	M/mix	F/F	F/mix	M/M	M/mix	F/F	F/mix	M/M	M/mix	F/F	F/mix
Neck pre	.02	.00	.00	.00	.05	.27	.12	.35	.00	.00	.01	.00
post	.02	.00	.00	.00	.14	.31	.27	.58	.03	.00	.07	.07
Shoulder pre	.07	.00	.09	.13	.08	.23	.10	.15	.04	.00	.09	.10
post	.11	.00	.11	.17	.11	.21	.22	.25	.04	.02	.11	.12
Biceps pre	.07	.00	.11	.08	.03	.19	.20	.10	.06	.00	.10	.15
post	.02	.00	.09	.08	.05	.15	.27	.23	.13	.00	.13	.15
Forearm pre	.00	.00	.09	.13	.03	.08	.12	.15	.04	.00	.09	.10
post	.00	.00	.11	.13	.05	.10	.15	.23	.01	.00	.13	.15
Hand pre	.00	.00	.04	.04	.00	.00	.24	.04	.00	.00	.01	.00
post	.00	.00	.13	.25	.00	.06	.54	.23	.01	.00	.09	.10

Front	Two-person				Three-person				Four-person			
	M/M	M/mix	F/F	F/mix	M/M	M/mix	F/F	F/mix	M/M	M/mix	F/F	F/mix
Chest pre	.07	.04	.04	.13	.03	.04	.02	.08	.11	.05	.10	.07
post	.11	.00	.06	.04	.08	.04	.17	.19	.09	.00	.12	.10
Abdomen pre	.07	.00	.04	.13	.05	.00	.15	.06	.06	.00	.10	.07
post	.13	.00	.11	.21	.08	.02	.20	.19	.04	.00	.13	.10
Hips pre	.04	.00	.09	.13	.05	.00	.24	.08	.06	.00	.15	.12
post	.13	.04	.09	.29	.05	.00	.15	.10	.10	.00	.12	.15
Thigh pre	.30	.04	.30	.25	.24	.33	.32	.21	.35	.05	.34	.32
post	.41	.00	.25	.33	.14	.27	.37	.35	.29	.12	.42	.34
Shin pre	.28	.12	.15	.21	.22	.10	.22	.06	.29	.00	.30	.24
post	.17	.00	.11	.33	.16	.04	.29	.29	.27	.12	.34	.32
Foot pre	.00	.00	.02	.00	.03	.02	.07	.06	.00	.00	.04	.00
post	.07	.00	.04	.00	.00	.02	.10	.11	.00	.00	.06	.05

Table A3. Pain, soreness and discomfort of the back of the body for two-, three- and four-person teams. (The initial code M or F indicated the gender of the respondent, the code following the slash indicates the gender of the other team members: M=male, F=female, mix=mixed-gender team).

Back	Two-person				Three-person				Four-person			
	M/M	M/ mix	F/F	F/ mix	M/M	M/ mix	F/F	F/ mix	M/M	M/mix	F/F	F/ mix
Neck pre	.20	.00	.17	.29	.32	.33	.54	.60	.09	.00	.22	.15
post	.26	.00	.28	.38	.30	.25	.61	.88	.11	.00	.30	.15
Shoulder pre	.17	.00	.21	.08	.16	.19	.34	.19	.08	.00	.21	.12
post	.15	.00	.31	.25	.19	.19	.37	.33	.10	.00	.28	.20
Biceps pre	.07	.00	.13	.08	.03	.08	.20	.13	.03	.00	.10	.17
post	.07	.00	.13	.08	.05	.04	.24	.23	.06	.00	.13	.22
Forearm pre	.02	.00	.09	.13	.03	.06	.17	.12	.03	.00	.09	.07
post	.02	.00	.17	.13	.05	.08	.20	.23	.05	.00	.15	.20
Hand pre	.02	.00	.04	.04	.00	.04	.07	.10	.01	.00	.01	.05
post	.02	.00	.06	.08	.00	.00	.29	.17	.04	.00	.09	.12

Back	Two-person				Three-person				Four-person			
	M/M	M/ mix	F/F	F/ mix	M/M	M/ mix	F/F	F/ mix	M/M	M/mix	F/F	F/ mix
Upper back pre	.28	.12	.26	.29	.41	.63	.37	.37	.24	.12	.24	.22
post	.35	.12	.32	.50	.41	.60	.73	.65	.28	.10	.34	.49
Mid-back pre	.46	.19	.38	.25	.97	1.31	.59	.40	.42	.27	.27	.20
post	.96	.46	.49	.54	1.27	1.63	1.15	1.08	.91	.73	.46	.51
Low-back pre	.41	.15	.36	.42	.76	.90	.63	.50	.19	.22	.33	.29
post	.67	.35	.66	.75	1.22	1.29	1.05	1.17	.42	.46	.62	.46
Thigh pre	.20	.12	.28	.29	.30	.31	.54	.23	.19	.05	.29	.24
post	.28	.04	.26	.17	.38	.31	.59	.42	.34	.07	.30	.34
Calf pre	.26	.12	.15	.25	.24	.15	.34	.13	.27	.05	.23	.27
post	.24	.08	.15	.17	.22	.15	.51	.33	.30	.07	.27	.29
Foot pre	.02	.00	.00	.00	.00	.04	.05	.04	.00	.00	.05	.00
post	.02	.00	.04	.04	.03	.00	.15	.12	.04	.00	.06	.05